NAIC-ID(RS)T-0590-96

NATIONAL AIR INTELLIGENCE CENTER

JAMMING OF LASER-GUIDED WEAPONRY

by

Fu Wei

19970414 144

Approved for public release:
distribution unlimited

NAIC- ID(RS)T-0590-96

HUMAN TRANSLATION

NAIC-ID(RS)T-0590-96 13 February 1997

MICROFICHE NR:

JAMMING OF LASER-GUIDED WEAPONRY

By: Fu Wei

Source: Unknown

Country of origin: China
Translated by: Leo Kanner Associates
F33657-88-D-2188
Requester: NAIC/TAEC/Frank Scenna
Approved for public release: distribution unlimited.

THIS TRANSLATION IS A RENDITION OF THE ORIGINAL FOREIGN TEXT WITHOUT ANY ANALYTICAL OR EDITORIAL COMMENT STATEMENTS OR THEORIES ADVOCATED OR IMPLIED ARE THOSE OF THE SOURCE AND DO NOT NECESSARILY REFLECT THE POSITION OR OPINION OF THE NATIONAL AIR INTELLIGENCE CENTER.	PREPARED BY: TRANSLATION SERVICES NATIONAL AIR INTELLIGENCE CENTER WPAFB, OHIO

GRAPHICS DISCLAIMER

All figures, graphics, tables, equations, etc. merged into this translation were extracted from the best quality copy available.

JAMMING OF LASER-GUIDED WEAPONRY

Fu Wei

ABSTRACT: Laser jamming has two forms: passive laser jamming and active laser jamming. This paper outlines the present status of development of laser jamming techniques.

KEY WORDS: laser jamming, passive jamming, concealed smoke screen, active jamming, deceptive jamming, blinding jamming.

Introduction

Owing to the superiorities such as high-precision guidance effect, strong anti-jamming capabilities, structural simplicity as well as low cost, laser-guided weapons have become a major interest of research and development in many countries and are largely deployed in military forces. According to statistics, over 200,000 laser-guided bombs are in service in military forces worldwide, and the number has been increasing at a rate of more than 10,000 per year. Likewise, this rapid development can also been seen in the production of many kinds of laser-guided missiles; for instance, the production of Hellfire alone will exceed 60,000. This apparently has brought a extremely severe challenge to the defense of ground targets, sea targets and air targets.

Today, the ever-increasing threat from lasers in the battlefield has spurred dramatic developments in laser jamming technology. At present, large numbers of passive laser jamming (smoke) equipment have been deployed in the military forces and have become an indispensable electronic warfare item of equipment used by modern military forces. Similarly, active laser jamming equipment and laser blinding weapons have also been put into use in actual battle in beginning to display their powerful performance.

Passive Laser Jamming Techniques

1.1. Laser Concealment Techniques

Laser concealment techniques are primarily designed for military capabilities that are likely to be detected by military equipment including laser rangefinders, laser target designators, and lidar, such as aircraft, warships, missiles, and ground military targets. The major concern with these techniques is to reduce target reflectivity and area. Thus far, two major laser concealment techniques that have been applied in military-oriented tanks, vehicles, and so on are as follows.

1) Reducing laser backward-scattering and enhancing diffuse reflection. Technically, a tank is coated with a particular paint to make its surface brightness get dull and become a diffuse reflecting body. As a result, the intensity of the reflected laser ranging/tracking signals can be decreased. Some fixed or semi-fixed targets, among other treatments, can be covered with a miniature cavity structure so that incident laser will be reflected back after repeated refraction and reflection in the cavity.

2) Adopting a laser camouflage net. This net can be coated with a laser-absorbing paint, and in structure, it either can be

designed in a absorptive multilayer sandwich form or it can be designed in a honeycomb form using composite material so that the laser can return back along the original path at the other end of the honeycomb. With this design, not only can the intensity of the transmitted laser signal be weakened, but also the arrival time of the reflected light can be delayed, which can increase the errors in laser ranging process.

Similarly, there are two kinds of laser concealment techniques applied in aircraft.

1) Adopting contour techniques

- Eliminating contour combination that may lead to a corner reflector effect;
- Converting backward-scattering to non-backward-scattering;
- Replacing mirror surface reflection with marginal diffraction;
- Replacing curved contours with flat contours;
- Reducing the number of scattering sources;
- Reducing aircraft dimensions;
- Screening one component with another component.

All the foregoing techniques can play a dual role in reducing the radar cross-section and reducing the laser cross-section.

2) Adopting material techniques

- Adopting absorptive material. The absorptive material can be classified into two categories, namely paint and structural type. Paint can be used to paint the surface of a target or adhere to the surface of a target; yet it is liable to come off under the impact of a high speed gas flow and also, it has a narrow working frequency bandwidth. To construct the structural type, a non-metal base material is made into a honeycomb shape or ripple shape, which is then coated with wave-absorbing material; or wave-absorbing fiber is incorporated into these structures.

- Adopting transmission material.
- Adopting light conductive material.

Normally, the material techniques can only be used to deal with a laser with single waveband or very narrow waveband.

1.2. Smoke Screen Jamming

The old application of smoke revived with the development of photoelectric weapons. As an important passive laser jamming tool, smoke was first brought into use in the Vietnam War. When the United States Air Force bombarded the Fu'an Power Plant in Hanoi, the Vietnamese army forces spread smoke in a timely manner, and what happened was that, out of the dozens of laser-guided bombs that American aircraft dropped, none of them hit the target. This example fully indicates that smoke is an effective tool in jamming laser-guided weapons.

In the fourth Middle East war, smoke also played a critically important role and brought even more attention to the smoke technology. As a former Soviet military spokesman phrased it: the smoke screen was the best tool in weakening the long-distance anti-tank weapon efficiency. When under attack, blanket smoke can reduce the efficiency of enemy weapons by 80%, while in defense, the application of confusion smoke can diminish the efficiency of enemy's weapons by 90%.

In 1992, a laser countermeasures simulation test was conducted by the U.S. Navy "Combat Vehicle Survival Assessment Crew" (CVSAC); this test fully demonstrated that the survivability and killing efficiency of a tank can be greatly increased once equipped with a laser alarm coupled with smoke shells. Technically, the strategy of combining a laser warning device with smoke proves much more efficient than with other countermeasures, such as seeking shelter, mobile dodging, etc.

Furthermore, the medium concentration smoke screen is much effective than highly-concentrated smoke screens because it allows the protected side to have partial sighting ability.

The smoke screen facilities deployed in various countries include smoke can, smoke launcher, smoke shell, smoke grenade, engine exhaust smoke system, helicopter smoke system, etc. Based on different needs, they can generate the smoke with the width ranging from dozens of meters to tens of thousands of meters, which can last from, in some cases, only 2s, the shortest, to a few minutes, dozens of minutes, or even longer. The smoke grains or mist drips thus formed usually range from 0.2 to 0.8μm with a number of $10^{12}/m^3$. Technically, smoke can effectively jam laser rangefinders, laser guidance systems as well as visible light and infrared light observation and sighting systems. There are five typical smoke devices as follows:

1) Fast smoke screen system for tank defense

This type of smoke screen can be mainly divided into two parts: one is an engine exhaust smoke-generating arrangement, in which smoke-generating oil is sprayed into the engine exhaust system, where it is heated and gasified, and then discharged and condenses in contact with air to form an oil-mist smoke screen. The features shown in this arrangement include cost-effectiveness and convenience in use, but it also suffers from a shortcoming of overly slow smoke generation.

The other variety is the smoke shell, widely used in tanks by NATO countries, France, Japan, and so on. In the late seventies, Britain developed the L8 series smoke shell especially for tanks, which is capable of building a 60m-wide and 8~10m-high smoke screen 25m away from the vehicle within 2.5s after launch; this smoke can last 3min at a wind speed 24km/h. Another 76mm anti-infrared smoke shell, produced again in Britain, can form a

40m-wide and 5m-high smoke 15~25m away from the tank within 3s after launch.

By introducing relevant technology from Britain, the United States developed the M239, M250 and M243 smoke launchers to be deployed on tanks and armored vehicles. Finally, a smoke shell made in Norway can generate a 80m wide smoke 30~40m away in front of the vehicle within 1s after launch.

2) Artillery smoke ammunition

Yellow phosphorus smoke-generating shells serve as the major ammunition used by many countries, which can generate rapid confusion smoke. For instance, the U.S. land forces have equipped their guns with many kinds of smoke-generating shells ranging from 60mm to 155mm, as well as the 105mm and 155mm hexachloroethane smoke-generating shells. The yellow phosphorous shell can form a smoke within 30s after detonation, which can shield visible light and near-infrared light. The yellow phosphorous shell fired by the improved version of M109A1 howitzer can generate a 250m-wide smoke screen which can last 10s with a remarkably improved shielding efficiency, while the smoke generation efficiency of the M825 type 155mm yellow phosphorous shell was improved by a factor of 3 compared with the old fashioned shells. In addition, a new powder made of water-free calcium carbonate and soot-absorbing titanium tetrachloride liquid currently is still under research in overseas countries.

3) Fast smoke screen system for helicopter defense

This system is primarily designed to deal with the tracking of confusion missiles. The M259 smoke-generating rocket developed in the United States can produce a smoke screen with a width as broad as thousands of meters 32m away, which can last 5min and shield in the 3~5μm and 8~14μm wavebands. A red

phosphorus smoke shell developed by Boeing, Inc., can form, under non-wind condition, a smoke 30m wide and 50m high, which can last 1min. A smoke-generating system developed in Sweden is mounted at the rear lower side of a helicopter, which can form a smoke screen 100m away within 2s after launch.

4) Large-area smoke-generating devices

These devices include the American-made M3A3 oil mist smoke launcher, the AN-M7 and M6 oil mist smoke-generating canister, the ABC-M5 hexachloroethane smoke-generating canister, etc. A total of 24 M3A3 smoke generators can form a 3km wide smoke within 20min. The BDSH-5 and BDSH-15 smoke-generating canister used in tanks of the former Soviet Union can produce a 100m-wide and 500m-long smoke at a wind speed 5m/s, which can last 10min. A helicopter can generate a 5km wide smoke within 2min.

5) Fast air defense smoke screen for ground target defense

The American 66mm smoke-generating rocket can rise to a height ranging from 30m to 120m within 1 to 2min and create a 180m-wide smoke wall within 10s. In addition, the type 80 red phosphorus smoke generators developed by Atlantic Research, Inc., can produce a 60~90m-high grounded smoke wall within 2s.

A wide frequency band multifunctional smoke screen has been now under research in many countries, which is intended for jamming visible light in the far-infrared waveband. Germany proposed an idea to add 10%~25% aromatic compounds such as polyethylene chloride in hexachloroethane so that the burned smoke-generating agent can release large amounts of carbon grains with a size ranging from 1 to 10μm. The smoke thus formed is expected to possess a much greater absorbing ability over infrared radiation above 3.2μm.

With aerosol as powder, the Swedish FFV266 mortar smoke-generating shell can produce a smoke, efficient enough to jam a sensor with a working wavelength as long as 14μm. A research report issued by the United States indicates that a water film with a thickness only 15μm can attenuate approximately 50% of infrared light with a wavelength 10μm. Evidently, water vapor aerosol can possibly be used to generate smoke screens for jamming far-infrared light.

The American M76 smoke shell went into service in 1985, which can screen wavebands from visible light up to infrared light with an effective screen time of 45s. Furthermore, the United States is also working on an aluminum foil-oil mist which is formed by aluminum foil with a diameter 2~20μm and thickness less than 0.3μm, and is fired from a oil mist smoke generator. This kind of smoke can jam infrared light with a wavelength 15μm.

In addition to all the foregoing passive laser jamming devices, dust can also be used to perform laser passive jamming. Dust composed of grains with a diameter ranging from several to dozens of μm can well attenuate long wave infrared laser. Some people suggest that a "dust generator" be mounted in the tank, which can collect dust brought by the caterpillar belt when the tank is moving, dry them, pulverize the dust, and finally spray them around the tank to shield laser. The advantages of this technique are: low cost and ready availability, while its disadvantage lies in that dust settles rapidly so that the launch operation has to be continuous.

The passive laser jamming devices currently under research, also include optical chaff, optical corner reflector, and Lambert's reflector. Due to their strong reflection of laser beams, they are able to produce false laser targets and conceal real targets.

2. Active Laser Jamming Techniques

2.1. Active Laser Deceptive Jamming

Laser deceptive jamming is designed to deceive and puzzle enemy laser rangefinders and laser-guided weaponry using their own laser jammers. Two approaches can be applied in realizing deceptive jamming of laser rangefinders. One approach is as follows: when irradiated by an enemy laser rangefinder signal, transmitting (or reflecting), in a very short delay time, a signal with the same wavelength and pulse width is generated along the original path so that the enemy will mistake one target with two targets. In this case, normally the enemy will manually shift the gear for a new measurement, which will certainly lead to missing the combat opportunity. The other jamming approach is re-transmitting the enemy's ranging pulse after a delay period so as to enlarge the error in the enemy rangefinding operations.

Germany developed a laser jammer in which numerous converging lenses are placed around the defense platform; the lenses are coupled with an optical-fiber delay line, while the other end of the fiber is connected to a reflector. Thus, when enemy laser rangefinding pulses are received, the laser signal will be reflected back along the original path through optical fiber delay line so that the enemy will receive a wrong ranging signal. This equipment, not requiring a laser transmitter, features simple structure and cost-effectiveness.

The expected effect of deceptive jamming of laser-guided weaponry is to deceive or puzzle the laser-guided weaponry by creating a false target so as to conceal the real target. Based on different jamming-generating techniques, active laser deceptive jamming can be classified as retransmission jamming and response jamming.

Retransmission jamming: automatically amplifying the laser pulse signal received by the laser alarming device and retransmitting it from a laser jammer so as to generate a laser deceptive jamming signal.

Response jamming: storing and accurately duplicating the received laser pulse signal to create a laser deceptive jamming signal.

To realize retransmission jamming, the jamming laser is required not only to have high pulse repetition frequency, but also must allow an extremely short transmission beam delay so that the laser jamming signal can fall into the time gate of the laser guidance system. In contrast, in response jamming, the laser is required to have a high pulse repetition frequency, wide range of pulse parameter variation, and high stability of leading parameters. An actual active laser deceptive jamming system always integrates retransmission jamming and response jamming.

Technically, a laser deceptive jamming system consists of a laser alarm subsystem, active jamming subsystem, laser jamming transmitter, and diffuse reflecting false target, etc. The major function of the laser alarm subsystem is to detect the laser threat signal and its arrival azimuth, and estimate the working wavelength of the laser device, while the active jamming subsystem is composed of signal sorter, pulse repetition frequency measurement meter, code identification processor, and synchronous retransmitter; it can be designed with a mixing mode of microcomputer and integrating circuit.

When the laser alarm subsystem receives a pulse signal, the signal sorter first executes azimuth sorting from different azimuths of multiple laser threat sources, and then performs pulse repetition frequency sorting for the multiple threat sources with the same azimuth by using time correlation among

coding pulses with the same series. The sorted single target pulse signals should be subject to high-precision pulse repetition frequency measurement to identify coding mode before being retransmitted synchronously.

The laser jamming signal transmitted from the laser jammer should be in total consistence with the laser guidance signal in working wavelength, pulse width, and coding mode. An optically false target is a diffuse reflecting body, whose major function is to radiate the beam energy received from the laser jammer into the hemispheric space, and introduce an angle deceptive signal in the guidance head angle tracking system.

The key techniques in achieving active laser deceptive jamming include:

· advanced laser alarming technique with high sensitivity, low false-alarm rate, wide range of detection wavelength, and wide dynamic range;

· multiple laser-threat-source signal-sorting technique;

· high precision pulse repetition frequency measurement technique;

· code (3-bit code, 4-bit code, 5-bit code, 6-bit code and pseudo-random code) identification technique;

· delay offset and synchronous retransmission technique;

· high performance laser technique with high output energy, high repetition frequency, short transmission beam delay, wide range of pulse parameter variation and high stability of major parameters.

Through modularization, the U.S. Army AN/GLQ-13 vehicle-borne laser countermeasures system can protect crucial ground targets with different shape and size from being attacked, and can operate independently through self-testing equipment. Analysis indicates that this system is designed with techniques including laser reconnaissance alarm, active laser jamming and

passive laser jamming.

The AN/VLQ-6 "Hardhat" vehicle-borne missile-countermeasures equipment is an item of in-service laser countermeasures equipment developed by Loral, Inc. While the AN/VLQ-8A missile countermeasures equipment was developed by Rockfield Sanders,, Inc. with a production run of over 1,000 units. During the "Desert Storm" operation, these two laser countermeasures equipment were both deployed in the Gulf region.

Another laser countermeasures system is the airborne laser ranging and countermeasures system (LARC), jointly developed by the United States and Britain. This system, equipped with four sensors covering the lower hemispheric air domain of aircraft, can realize jamming by increasing laser-arrival azimuth and time, and aiming the countermeasures beams at a particular laser threat source and transmitting them.

Based on this countermeasures systems, the U.S. Tank and Automatic Vehicle Command (TACOM) signed an agreement with Houston, Inc., to produce a trial laser-target-decoy system (LATADS), which will become part of an integrating defense system.

2.2.Laser Blinding Jamming

2.2.1. Laser Blinding Weaponry

Laser blinding weaponry can jam or damage periscopes, sighting devices, low-light-level night-vision devices, infrared imagers, laser rangefinders, laser target designators, and laser automatic trackers, etc., and can even directly destroy the seekers of laser-guided weaponry, as well as blind human eyes. Evidently, laser blinding weaponry are extremely effective laser countermeasures weapons.

During the Gulf War, the American forces used two kinds of laser blinding weapons, namely the AN/VLQ-7 Stingray combat defense system and AN/PLQ-5 laser countermeasures system (LCMS). The AN/VLQ-7 Stingray combat defense system, developed by Martin Marietta, Inc., was mounted in Bradley fighting vehicles. This system can capture targets using the "cat's- eye effect", and, with a CO_2 laser with an average power 1kW, and a Nd:YAG laser and Nd:YAG frequency multiplication laser with 100mJ output energy, can destroy military photoelectric equipment 8km away as well as damage human eyes over even greater distances. This system, equipped with a wide-view search and acquisition setup, can perform positioning over several tanks simultaneously, and transmit laser beams to blind the photoelectric sensors in these tanks to make them lose mobility, and finally destroy them by firing anti-tank missiles.

On the basis of he Stingray laser weapon, the Outrider combat protection system was developed. In this system, the infrared target acquisition system is combined with the Stingray laser device, and a more compact Stingray weapon system is mounted in the vehicle. Currently, Martin Marietta, Inc., is supplying this weapon to the task forces of the Army and Navy landing parties. In February 1994, the U.S. Marine Corps financed the initial demonstration of this system.

AN/PLQ-5, developed by Rockfield Sanders, Inc., is a portable laser blinding weapon, which is mounted on an M16A2 rifle to counterattack optical equipment and photoelectric sensors. This weapon can also instruct a helicopter to find a landing area. It consists of a laser irradiator and a day-and-night sighting device. These two components are mounted on an M16 rifle, while the battery package can be carried at the user's back, with a capacity of 3000shots. The AN/PLQ-5 can also be mounted on vehicles, aircraft or small boats. Typically, in an actual combat, an operator first searches for a target on the

battlefield with the sighting device. When he finds a target in the field of view using the "cat's-eye effect", he pulls the trigger on the weapon to fire laser pulses over an effective distance of more than 2km.

The AN/PLQ-5 adopts a light pumped, neodymium glass laser or discolored gem laser to transmit near-infrared laser beams. The inherent instable condition of infantry is favorable for the destructive effect of the PLQ-5, and with laser scattering, large amounts of components in the photoelectric equipment can be destroyed.

Based on Stingray technology, the United States developed an airborne laser weapon called Corolla Prince, which features even higher output power and longer operational distances. Primarily, this weapon is designed to blind ground-based optical and photoelectric tracking systems. The prototype of this weapon was already finalized, and the weapon is scheduled to be brought to use in the nineties.

An advanced airborne optical jamming suspended cabin developed in the United States is composed of a muzzle-flash detector, Nd:YAG laser, and a frequency multiplication Nd:YAG laser. This weapon is intended for dealing with air defense weaponry and is scheduled to be in service in the nineties.

An airborne flash laser jamming system was developed in the fall of 1988 by the U.S. Air Force. With a low-power chemical laser manufactured by TRW, Inc, this system is able to transmit an infrared laser beam over appropriate distances to deceive or baffle infrared-guided missiles and make them miss the target.

A British shipborne laser dazzling sighting device was developed on the basis of industrial lasers. This device features manually sighting, pulse mode operation, and an

effective range of approximately 5km. In the Falklands conflict, this weapon was applied to temporarily blind Argentine pilots and caused three aircraft to crash.

Among portable laser blinding weapons, we can also name the American Dazzler and Cobra laser, etc. These two weapons are capable of blinding soldiers or damaging the photoelectric sensors and periscopes mounted in vehicles.

Recently, a ZM-87 portable laser jammer was displayed at an exhibition sponsored by the North China Industry Incorporation. This device can blind or dazzle human eyes over effective distances of 3km, or even 5km with an amplifier.

The trends in the development of laser blinding weapons focuses on miniaturization and improvement of reliability as well as the application of diode pumped solid-state lasers. Another tendency is to employ wavelength-tunable lasers which are difficult to be counterattacked.

Both laser deceptive jamming and laser blinding jamming feature fast reaction speeds, which fact is vitally important in actual battle. For instance, a laser-guided missile at a speed of 2Ma is launched from a Russian helicopter Hind 3~4km away, and the time needed for launching before hitting the target is only 6.4 to 8.4s.

As a comparison, according to results from foreign research, the reaction time of a tank equipped with a laser alarm is as follows: generating a smoke screen as soon as a warning signal is received requires only 5s; firing guns for suppression takes 4.2s; mobile dodging requires 3s; turning the vehicle to make the thickest protective armor face the threat direction needs 3s, while laser deceptive jamming and laser blinding jamming take only 1s.

2.2.2. One-Time Laser Blinding Shell

The one-time laser blinding shell is also under research in overseas countries, such as intense light blinding shell, which serves to destroy various enemy photoelectric reconnaissance equipment through radiating extremely intensive flashes (laser beams). In this case, the explosives together with inert gases like argon, neon and xenon are placed in the shell so that gases at high temperatures and pressures will be generated after the explosives are ignited, forming plasma at temperatures as high as approximately 1000^0C, accompanied with an extremely strong flash. This flash can generate directional and omnidirectional radiation with a wavelength covering the ultraviolet to the infrared waveband. This kind of shell can be fired through ordinary howitzers, mortars or gravity bombs, or even thrown as grenades.

The U.S. Military Equipment Research, Development and Engineering Center invested large amounts of manpower, material, and funding in developing laser grenades. Recently, they finalized two kinds of laser grenades, namely scattering-radiation and directional-radiation grenades. These grenades can generate high efficiency laser beams through high explosive oscillation coupled with thermal inert gases to paralyze the normal operation of the optical sighting devices and laser rangefinders mounted in tanks as well as the detection system of laser-guided weaponry. In addition, they can dazzle or blind tank crews.

Another development is a miniature pulsed chemical laser mounted in the warhead of a shell round. When the shell round overflies a target region, the laser device is excited to generate a very intense laser beam and form an extremely strong impact wave and high-temperature and high-pressure plasma in front of the target, which can destroy various kinds of tanks, vehicles or photoelectric devices in the observation stations as

well as blind human eyes.

At the same time, the United States is also attempting to place a miniature laser dye rod and a flash device in a grenade with a diameter of approximately 40mm; this grenade can be used to attack small targets on the battlefield through a simple launch device.

Compared with laser blinding weaponry, the laser blinding shell round has the following superiorities: longer operating distances (able to blind targets 20km away), not requiring accurate aiming, not exposing the launch position and convenience in battlefield service.

2.3. Laser Destruction

Laser destruction can perform "hard destruction" of laser-guided weapon systems using high energy laser weapons or anti-laser radiation missiles. In high-energy laser weapon systems, the lasers commonly used are chemical lasers, free-electron lasers, and CO_2 aerodynamic lasers. The ship-borne high energy laser weapon developed by TRW, Inc., in the United States adopts a deuterium fluoride laser which is about to be successfully developed. However, due to technical difficulties and costs, high-energy laser weapons will not be able to serve the armed forces in the short term.

The United States is currently working on the development of an anti-laser radiation missile designed to detect and track an enemy laser threat source before destroying it. This missile is expected to be brought in use in the late nineties.

REFERENCES

1. 刘帆. 光电隐身技术探讨. 现代军事，1991(7)
2. 中国国防科技信息中心. 外军武器装备现状及发展趋势. 解放军出版社，1991
3. 付伟. 简论舰载激光有源干扰技术. 造船工程学会雷达与电子对抗研讨会，1992
4. 付伟. 迅速发展的军用激光设备. 光电对抗与无源干扰，1995(3)

This paper was received on October 26, 1995. The author is an engineer for the No. 35 Research Institute under the Ministry of Electronics.